Source model of the 2005 Miyagi-Oki, Japan, earthquake from broadband strong motion simulation by the empirical Green's function method

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Abstract

We estimate the source model of the M7.2 interplate earthquake which occurred offshore of Miyagi Prefecture (Miyagi-Oki region), northeast Japan, from broadband strong motion modeling using the empirical Green's function (EGF) method (Irikura, 1986; Miyake et al., 2003). The source model is composed of two strong motion generation areas (SMGA1 and SMGA2). SMGA represents a large slip-velocity area within the total rupture area and has successfully explained the observed broadband waveforms.

Location of SMGA1 is determined using the arrival time difference between the first motion and the first main phase in the P-wave portion (Takenaka et al., 2006). Then, we estimate the size, rise time, rupture propagation direction of SMGAs, and the rupture starting point of SMGA2 by fitting the synthetic waveforms into the observed ones for the S-wave portion over wide frequency range. This is achieved by minimizing the sum of the misfits of the velocity waveforms (0.2-1Hz) and the acceleration envelopes (0.2-10Hz) using the genetic algorithm.

SMGAs correspond to the two major large slip areas estimated from waveform inversion (Wu and Koketsu, 2006). This indicates that broadband strong motions are radiated from the concentrated areas on the fault. Stress drop of the shallower SMGA1 is 17.6MPa while that of the deeper SMGA2 is 34.1MPa. Comparison with the distribution of SMGAs of the previous 1978 Miyagi-Oki earthquake estimated by Kamae et al. (2002) shows that two SMGAs of the 2005 event do not overlap those of the 1978 event. M6-8 class interplate earthquakes, including the 2005 Miyagi-Oki one, have smaller SMGAs than crustal earthquakes for the same seismic moment, which indicates that SMGA stress drop of interplate earthquakes is larger than that of crustal earthquakes.

Introductions

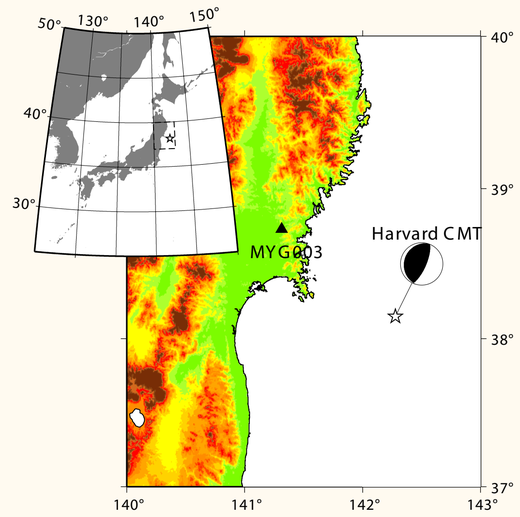

Fig. 1 : The epicenter and focal mechanism of the 2005 Miyagi-Oki earthquake.

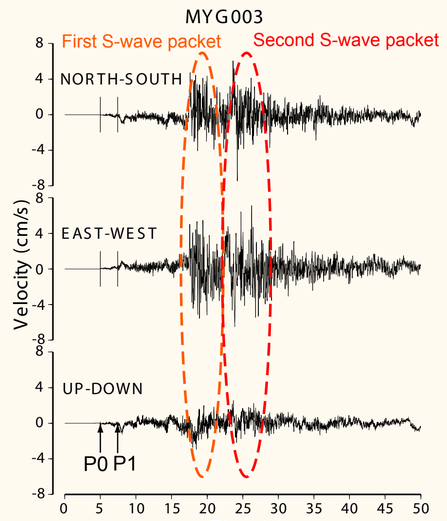

Fig. 2 : Velocity waveforms at the station MYG003.

Assumption for source model

- Two SMGAs (SMGA1 and SMGA2) for explaining two major S-wave packets
- SMGA1 could be located away from the hypocenter

Methodology and Results

1. Determination of Hyp1, rupture starting point of SMGA1

Time difference between P0 radiated from Hyp0 and P1 from Hyp1 is modeled assuming that Hyp1 is located on the fault plane.

$$T_{P1-P0} = T_{rupture} - \sqrt{\xi_1^2 + \xi_2^2}\cos\Psi / V_P$$

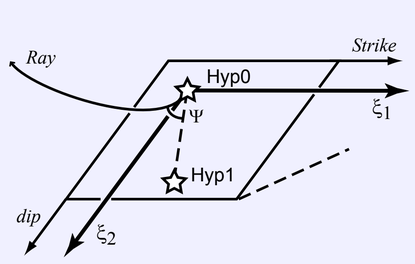

Fig. 3 : Geometrical settings for locating Hyp1. (Takenaka et al., 2006)

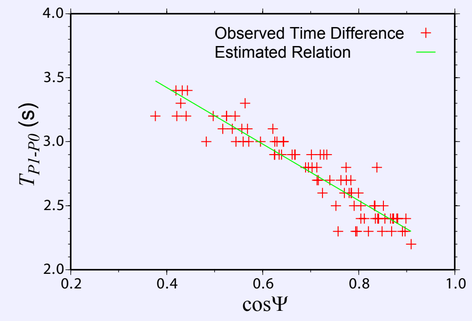

Fig. 4 : Estimated relationship between T_{P1-P0} and cosΨ.

2. Estimation of SMGA parameters from broadband strong motion simulation by EGF simulation

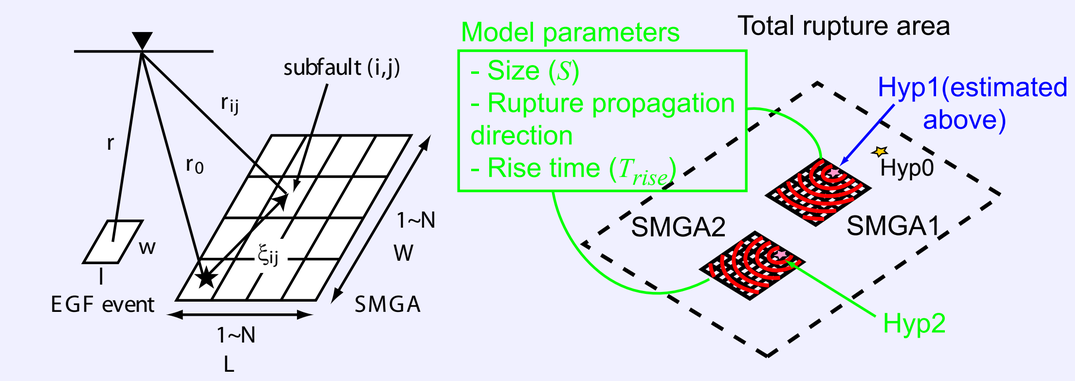

Fig. 5 : Schematic illustration of the EGF method and model parameters to estimate using the genetic algorithm (GA).

$$misfit\_for\_GA = \frac{\int (u_{obs} - u_{syn})^2 dt}{\sqrt{\int u_{obs}^2 dt}\sqrt{\int u_{syn}^2 dt}} + \frac{\int (e_{obs} - e_{syn})^2 dt}{\sqrt{\int e_{obs}^2 dt}\sqrt{\int e_{syn}^2 dt}}$$

Table 1. Estimated SMGA parameters

	S (km^2)	M_0 (Nm)	Δσ (MPa)	T_{rise} (s)	$T_{rupture}$ (s)
SMGA1	9.6 × 9.6	6.39×10^{18}	17.6	0.33	4.3
SMGA2	7.2 × 7.2	5.23×10^{18}	34.1	0.27	11.3

Rupture velocity of SMGA is 3.15km/s, 70% of *Vs*.

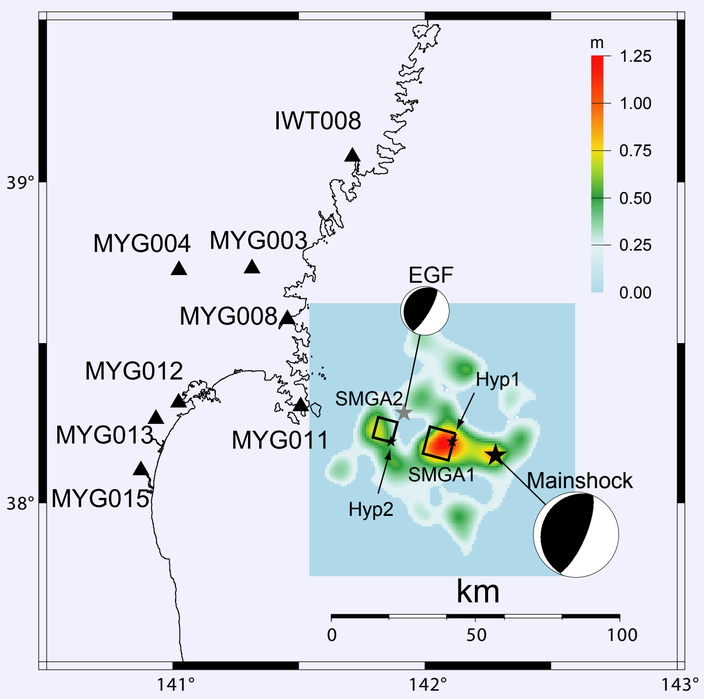

Fig. 6 : Comparison of the estimated SMGAs and slip distribution inferred from low-frequency waveform inversion (Wu and Koketsu, 2006).

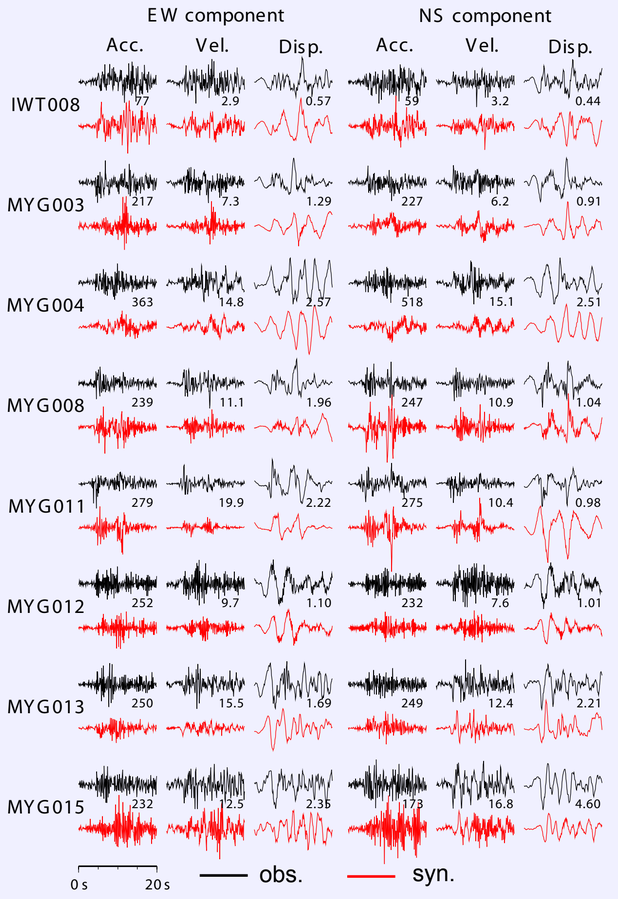

Fig. 7 : Comparison of observed and synthetic waveforms (0.2-10Hz).

Discussions

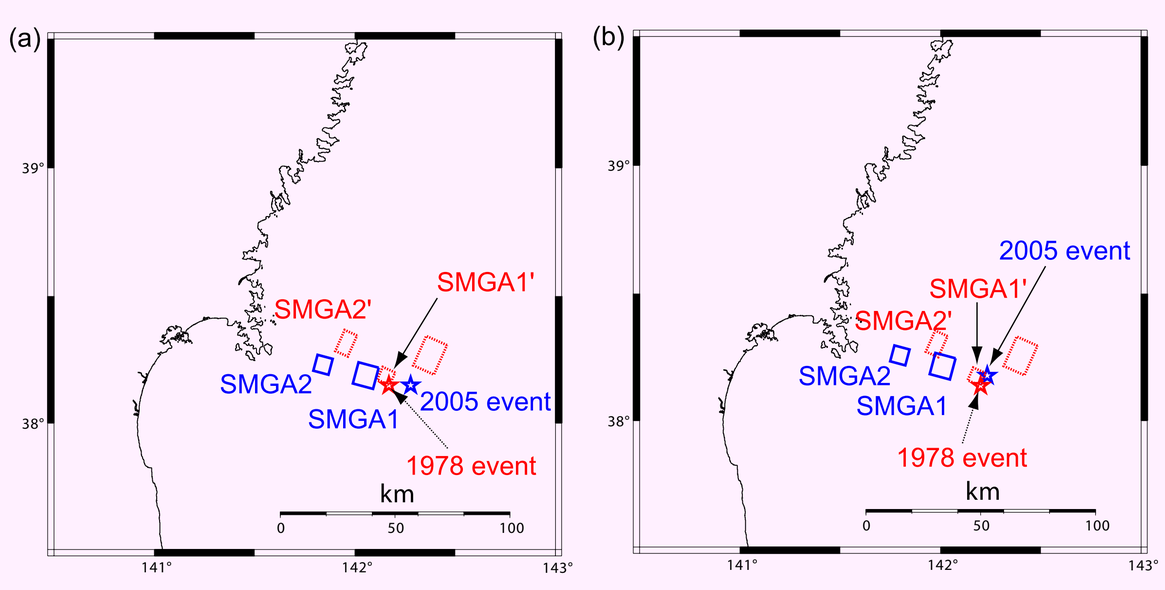

Fig. 8 : Comparison with the previous 1978 event (Kamae et al., 2002). (a) The hypocenters are determined by JMA. (b) The hypocenters are determined by Okada et al. (2005).

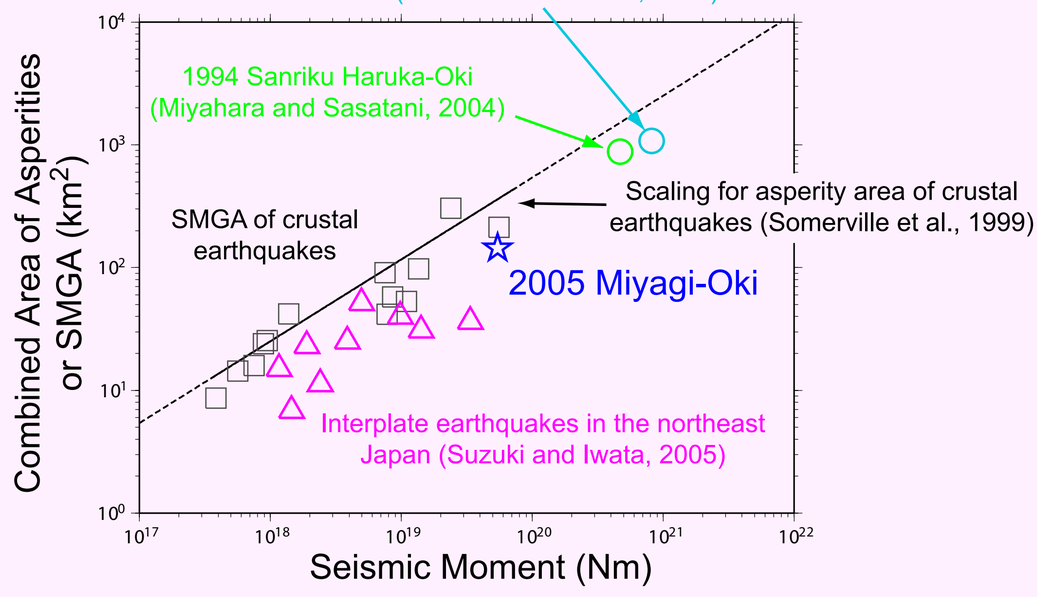

Fig. 9 : Scaling relationship between the combined area of SMGAs and the seismic moment.

Conclusions

- We estimated the source model of the 2005 Miyagi-Oki, Japan, earthquake based on the broadband strong motion simulation using the EGF method.
- Broadband strong motions are mainly radiated from the large slip areas revealed by the low-frequency waveform inversion of strong motion data.
- The stress drop of the SMGAs, which controls high-frequency wave radiation, is estimated to be 17.6MPa for SMGA1 and 34.1MPa for SMGA2.
- Two SMGAs of the 2005 Miyagi-Oki earthquake do not overlap those of the previous 1978 event.
- Combined area of the SMGAs is smaller than that expected for the crustal earthquakes, which is consistent with the tendency observed for the interplate earthquakes.